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EXOBIOLGY AND THE ORIGIN OF LIFE

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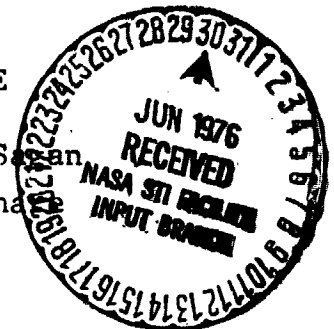


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COMPLETED WORK

Following is a partial list of recent papers published or in press in 1975-76 and supported wholly or in part by NASA Grant NGR 33-010-101. All authors are affiliated with the Laboratory for Planetary Studies except for paper 4 which is jointly authored by Carl Sagan and Joshua Lederberg of Stanford University.

- (1) Particles, Environments and Possible Ecologies in the Jovian Atmosphere (Astrophysical Journal Supplement, to be published.)

The eddy diffusion coefficient is estimated as a function of altitude, separately for the Jovian troposphere and mesosphere. The growth-rate and motion of particles is estimated for various substances: the water clouds are probably nucleated by NH_4Cl , and sodium compounds are likely to be absent at these levels. Complex organic molecules produced by the $\text{Ly } \alpha$ photolysis of methane may be the absorbers in the lower mesosphere which account for the low reflectivity of Jupiter in the near ultraviolet. The optical frequency chromophores

are localized at or just below the Jovian tropopause. Candidate chromophore molecules must satisfy the condition that they are produced sufficiently rapidly that convective pyrolysis maintains the observed chromophore optical depth. Organic molecules produced by ultraviolet light and polymeric sulfur seem to fail this test, even when a slow, deep circulation pattern, driven by latent heat, is present. However, Jovian photoautotrophs in the upper troposphere satisfy this condition well, even with fast circulation, assuming only biochemical properties of comparable terrestrial organisms. Unless buoyancy can be achieved, a hypothetical organism drifts downwards and is pyrolyzed. An organism in the form of a thin, gas-filled balloon can grow fast enough to replicate if (i) it can survive at the low mesospheric temperatures, or if (ii) photosynthesis occurs in the troposphere. If hypothetical organisms are capable of slow, powered locomotion and coalescence, they can grow large enough to achieve buoyancy. Airborne ecological niches for sinkers, floaters and hunters appear to exist in the Jovian atmosphere.

{A draft of the penultimate version of this paper is attached as Appendix B.}

- (2) Cyclic Octatomic Sulfur: A Possible Infrared and Visible Chromophore in the Clouds of Jupiter, Science, Volume 189, pp. 722-723, 1975.

A brown polymeric material, produced under simulated Jovian conditions, is composed primarily of cyclic octatomic sulfur, although a range of complex organic compounds is also present. The polymeric sulfur, produced from the ultraviolet photolysis of hydrogen sulfide, exhibits its strongest band at 465 reciprocal centimeters, in fair agreement with the frequency of the unidentified Jovian absorber recently announced by Houck et al. Polymeric octatomic sulfur may be an important constituent of the Jovian clouds.

- (3) On the Temperature Dependence of Possible S_8 Infrared Bands in Planetary Atmospheres, Icarus, in press.

Measurements of the temperature dependence between 77 and 333K of the infrared spectrum of cyclic octatomic sulfur suggest that the 23 μm Jovian feature very tentatively identified by Houck et al. (1975) is not due to S_8 ; and that the

temperature dependence of the frequency of the 835 cm^{-1} band of S_8 may be a useful temperature marker in planetary studies.

- (4) The Prospects for Life on Mars: A Pre-Viking Assessment, Icarus, in press.

Mariner 9 has provided a refutation or reinterpretation of several historical claims for Martian biology, and has permitted an important further characterization of the environmental constraints on possible Martian organisms. Four classes of conceivable Martian organisms are identified, depending on the environmental temperature, T , and water activity, a_w : Class I, high T , high a_w ; Class II, low T , high a_w ; Class III, high T , low a_w ; and Class IV, low T , low a_w . The Viking lander biology experiments are essentially oriented towards Class I organisms; although arguments are given for the conceivable presence on Mars of organisms in any of the four classes. Organisms which extract their water requirements from hydrated minerals or from ice are considered possible on Mars, and the high ultraviolet flux and low oxygen partial pressure are considered to be negligible impediments to Martian biology.

Large organisms, possibly detectable by the Viking lander cameras, are not only possible on Mars, they may be favored. The surface distribution of Martian organisms and future search strategies for life on Mars are discussed.

- (5) The Canals of Mars: An Assessment after Mariner 9, Icarus, Volume 25, pp. 602-612, 1975.

The Lowellian canal network has been compared with the results of Mariner 9 photography of Mars. A small number of canals may correspond to rift valleys, ridge systems, crater chains, and linear surface albedo markings. But the vast bulk of classical canals correspond neither to topographic nor to albedo features, and appear to have no relation to the real Martian surface.

- (6) The Recognition of Extraterrestrial Intelligence, Proceedings of the Royal Society of London, B 189, pp. 143-153, 1975.

A necessary but not sufficient condition for the recognition of extraterrestrial intelligence is a significant departure from thermodynamic equilibrium. This can

clearly be discerned in the inverse problem of the detection of terrestrial intelligence from a distance. Photography of the Earth in reflected sunlight reveals no clear sign of life until 100 meters resolution is achieved, at which point the agricultural and urban reworking of the Earth's surface in rectangular arrays first becomes obvious. This pattern is however detectable only over interplanetary distances. Mars exhibits no such patterns. The departure from radiative equilibrium -- represented by radio, television and radar technology -- in the microwave spectrum of the Earth is by contrast easily detectable over interstellar distances. Even with a technology no more advanced than our own, a civilization on a planet of a nearby star could easily determine, by autocorrelation techniques, the artificiality of these radio signals. Intentional interstellar radio messages should be detected and decrypted far more readily. Possible message contents for interstellar discourse of a modulated signal at any accessible frequency include (1) m -dimensional imagery represented by the transmission of numbers which are the products of m prime numbers; and (2) the use of a common mathematics, physics or astronomy to convey a range of information on more difficult subjects. The only direct

attempts to date to communicate with extraterrestrial intelligence -- the plaques aboard the Pioneer 10 and 11 spacecraft -- are briefly discussed.

(7) Pattern Recognition and Zeta Reticuli, Astronomy, Volume 3, Number 7, pp. 39-40, 1975.

(8) The Zeta Reticuli Affair Astronomy Volume 3, Number 9, pp. 16-17, 1975.

The supposed agreement between the "star map" of the Hill case with a map of the distribution of nearby stars of solar spectral type from the Gliese catalog is shown to be no better than is to be expected by chance, and therefore not good evidence of visitations to the Earth by extraterrestrial civilizations. Prominent among the statistical errors in some other discussions on this matter is the fallacy of the enumeration of favorable circumstances.

(9) An Introduction to the Problem of Cosmic Communication, in Cosmic Communication, C. Ponnampertuma and A.G.W. Cameron, eds., Boston, Houghton Mifflin, 1975.

- (10) Biogenesis, Abiogenesis, Biopoesis and All That,
Origins of Life, Volume 6, page 577, 1975.
- (11) The Search for Extraterrestrial Intelligence,
Scientific American, Volume 232,
pp. 80-89, 1975. Available as Scientific American
offprint Number 347, San Francisco, W.H. Freeman
and Company, 1976. Reprinted as "En Busca de la
Inteligencia Extraterrestre" in Revista de Occidente
November, 1975, pp. 84-92 (Madrid).

In addition, substantial progress was made in several other areas treated more fully in the body of the renewal proposal, but including: extensive gas chromatograph/mass spectrometer studies of brown polymeric material produced both by electric discharge and by ultraviolet light in experiments on prebiological organic chemistry and on the present organic chemistry of the atmosphere of Jupiter; an analysis of the differential reflectivity of Jovian bands and belts in order to distinguish between candidate chromophores including sulfur compounds and complex organic polymers; and the execution and analysis of an extensive

series of observations at the Arecibo Radio Observatory for possible radio messages from extraterrestrial civilizations both within our Galaxy and in other galaxies.

During the past grant year the principal investigator has served as Chairman of the Division for Planetary Sciences of the American Astronomical Society; as Chairman of the Astronomy Section of the American Association for the Advancement of Science; and was elected to the Physical Sciences Committee, SPAC, NASA Headquarters. He served as Jacob Bronowski Lecturer at the University of Toronto, as Royal Institution Lecturer at the Royal Institution in London and as Danz Lecturer at the University of Washington. He also received three honorary Doctor of Science degrees, from Rensselaer Polytechnic Institute, Denison University, and Skidmore College. Among his popular works published which relate to the subject matter of this grant were British, German, French, Spanish, Dutch and Italian editions of The Cosmic Connection: An Extraterrestrial Perspective, and a British edition of Other Worlds; as well as "The Solar System" (Scientific American, Vol. 233, pp. 22-31) and "The Planets" in Man and Cosmos: The Guggenheim Lectures (New York, W.W. Norton), pp. 68-100.